**Supplementary Data**

Radionuclide measurement for each waste source were carried out 3 times using a gamma spectrometer. All of the sample volume is 1 litre in marinelli beaker. The measurement results are described in the table and figure below.

1. Radionuclides measurement result for KPK01-BB01 storage tank liquid radwaste (LALR)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  |
| Co-60 | 9.23 | 8.8 | 9.8 | 9.28 | 0.41 |
| Zn-65 | 9.86 | 9.9 | 9.8 | 9.85 | 0.04 |
| Na-24 | 2.3 | 2.2 | 2.1 | 2.20 | 0.08 |
| Cr-51 | 1 | 1.1 | 1.3 | 1.13 | 0.12 |



**Figure 3:** Radionuclide contents in LALR of KPK01-BB0**1**

1. Radionuclides measurement result for KPK01-BB02 storage tank liquid radwaste

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** | |  |  |
| Zn-65 | 0.096 | 0.092 | | 0.094 | 0.094 | 0.002 |
| Fe-59 | 0.0256 | 0.0247 | | 0.0255 | 0.025 | 0.000 |
| Co-60 | 0.0225 | 0.0219 | | 0.0223 | 0.022 | 0.000 |
| Sb-124 | 0.00115 | 0.00113 | | 0.00114 | 0.001 | 0.000 |



**Figure 4:** Radionuclide contents in LALR of KPK01-BB02

1. Radionuclides measurement result for KPK-02 storage tank liquid radwaste

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Nuclides** | | **Activity, Bq** | | | **Average** | **Std-dev** |
| **1st** | **2nd** | **3rd** |
| Ni-65 | 193 | | 170 | 168.4 | 177.13 | 11.24 |
| Te-129M | 29 | | 25 | 24 | 26.00 | 2.16 |
| Kr-89 | 31 | | 19 | 24 | 24.67 | 4.92 |
| Cr-51 | 5.67 | | 6.1 | 4.22 | 5.33 | 0.80 |
| Na-24 | 7.4 | | 5.4 | 2.6 | 5.13 | 1.97 |
| Co-60 | 3.71 | | 3.1 | 3.67 | 3.49 | 0.28 |
| Te-127M | 1.8 | | 1.65 | 1.72 | 1.72 | 0.06 |
| Co-58 | 1.025 | | 1.03 | 1.1 | 1.05 | 0.03 |
| Ce-144 | 0.49 | | 0.52 | 0.4 | 0.47 | 0.05 |
| Mn-56 | 0.47 | | 0.43 | 0.41 | 0.44 | 0.02 |
| La-140 | 0.256 | | 0.276 | 0.24 | 0.26 | 0.01 |
| Ba-140 | 0.257 | | 0.22 | 0.289 | 0.26 | 0.03 |
| Fe-59 | 0.227 | | 0.26 | 0.265 | 0.25 | 0.02 |
| Te-132 | 0.156 | | 0.151 | 0.178 | 0.16 | 0.01 |
| I-131 | 0.15 | | 0.121 | 0.145 | 0.14 | 0.01 |
| Xe-133 | 0.135 | | 0.074 | 0.054 | 0.09 | 0.03 |
| I-133 | 0.1 | | 0.082 | 0.072 | 0.08 | 0.01 |
| Zr-95 | 0.016 | | 0.18 | 0.02 | 0.07 | 0.08 |
| Ce-141 | 0.05 | | 0.086 | 0.075 | 0.07 | 0.02 |
| I-132 | 0.059 | | 0.063 | 0.077 | 0.07 | 0.01 |
| Xe-135 | 0.047 | | 0.045 | 0.092 | 0.06 | 0.02 |
| Nd-147 | 0.017 | | 0.017 | 0.047 | 0.03 | 0.01 |
| Te-131M | 0.031 | | 0.02 | 0.025 | 0.03 | 0.00 |
| Nb-95 | 0.017 | | 0.017 | 0.022 | 0.02 | 0.00 |



**Figure 5:** Radionuclide activities on MALR of storage tank KPK02

1. Radionuclides measurement result for beam tube S1 liquid radwaste

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  |
| Zn-65 | 2260 | 2220 | 2230 | 2236.67 | 20.82 |
| Co-60 | 728 | 728 | 720 | 725.33 | 4.62 |
| Ba-133 | 280 | 275 | 276 | 277.00 | 2.65 |
| Ce-144 | 259 | 266 | 255 | 260.00 | 5.57 |
| Eu-155 | 180 | 176 | 174 | 176.67 | 3.06 |
| Ra-226 | 179 | 175 | 173 | 175.67 | 3.06 |
| Th-232 | 140 | 138 | 138 | 138.67 | 1.15 |
| Eu-154 | 138 | 136 | 136 | 136.67 | 1.15 |
| Co-57 | 27 | 26 | 25 | 26.00 | 1.00 |
| Rh-106 | 23 | 20 | 20 | 21.00 | 1.73 |
| Ta-182 | 21 | 17.9 | 16 | 18.30 | 2.52 |
| Zr-95+ | 14.4 | 23.0 | 23 | 20.13 | 4.97 |
| Mn-54 | 13 | 11.8 | 10.0 | 11.60 | 1.51 |
| Ru-103 | 4.4 | 7.5 | 3.0 | 4.97 | 2.30 |
| Cs-134 | 5 | 4 | 3.7 | 4.23 | 0.68 |



**Figure 6:** Radionuclide activities on MALR of beam tube S1

1. Radionuclides measurement result for beam tube S2 liquid radwaste

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  |
| Zn-65 | 4040 | 3970 | 5390 | 4466.67 | 653.52 |
| Co-60 | 1420 | 1410 | 1830 | 1553.33 | 195.68 |
| Ce-144 | 279 | 316 | 362 | 319.00 | 33.95 |
| Mn-54 | 21 | 19.6 | 25 | 21.87 | 2.29 |
| Ag-110m | 5.9 | 10.4 | 13.3 | 9.87 | 3.04 |



**Fig. 7.** Radionuclide activities of MALR beam tube wastewater S2

1. Radionuclides measurement result for beam tube S3 liquid radwaste

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  |
| Eu-155 | 47 | 48 | 48 | 47.67 | 0.58 |
| Eu-154 | 4.7 | 4.9 | 4.9 | 4.83 | 0.12 |
| Co-60 | 3.2 | 3.3 | 3.3 | 3.27 | 0.06 |
| Cs-137 | 3.1 | 3 | 3 | 3.03 | 0.06 |
| Cs-134 | 2 | 3 | 3 | 2.67 | 0.58 |



**Fig. 8.** Radionuclide activities of MALR beam tube wastewater S3

1. Radionuclides measurement result for beam tube S4 liquid radwaste

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  | |
| Zn-65 | 1090 | 1070 | 1065 | 1075.00 | 10.80 |
| Co-60 | 392 | 392 | 392.5 | 392.17 | 0.24 |
| Ce-144 | 700 | 689 | 689 | 692.67 | 5.19 |
| Cd-109 | 240 | 235 | 230 | 235.00 | 4.08 |
| Mn-54 | 68 | 65 | 60 | 64.33 | 3.30 |
| Hg-203 | 40 | 38 | 35 | 37.67 | 2.05 |
| Ag-110m | 17.5 | 15 | 14 | 15.50 | 1.47 |
| Co-57 | 17 | 15 | 13 | 15.00 | 1.63 |
| Cs-134 | 6.4 | 6 | 5 | 5.80 | 0.59 |
| Ce-144 | 490 | 485 | 482 | 485.67 | 3.30 |
| Eu-155 | 290 | 285 | 280 | 285.00 | 4.08 |
| Cs-137 | 9.4 | 8 | 7 | 8.13 | 0.98 |



**Figure 9:** Radionuclide activities of MALR beam tube wastewater S4

1. Radionuclides measurement result for beam tube S5 liquid radwaste

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | | **STDEV** |
|  | **1st** | **2nd** | **3rd** |  | |  |
| Nd-147 | 0.016 | 0.012 | 0.01 | 0.01 | 0.002 | |
| Ru-103 | 0.02 | 0.01 | 0.01 | 0.01 | 0.005 | |
| Zr-95 | 0.0274 | 0.0253 | 0.0244 | 0.03 | 0.001 | |
| Nb-95 | 0.0281 | 0.0261 | 0.0242 | 0.03 | 0.002 | |
| Te-132 | 0.054 | 0.048 | 0.048 | 0.05 | 0.003 | |
| I-132 | 0.076 | 0.072 | 0.071 | 0.07 | 0.002 | |
| Ce-141 | 0.084 | 0.082 | 0.082 | 0.08 | 0.001 | |
| Fe-59 | 0.089 | 0.071 | 0.068 | 0.08 | 0.009 | |
| Xe-133 | 0.13 | 0.1 | 0.11 | 0.11 | 0.012 | |
| Ce-144 | 0.207 | 0.201 | 0.21 | 0.21 | 0.004 | |
| I-131 | 0.279 | 0.261 | 0.26 | 0.27 | 0.009 | |
| Ba-140 | 0.49 | 0.45 | 0.45 | 0.46 | 0.019 | |
| La-140 | 0.532 | 0.528 | 0.522 | 0.53 | 0.004 | |
| Co-60 | 0.93 | 0.89 | 0.89 | 0.90 | 0.019 | |
| Cr-51 | 2.01 | 2 | 2 | 2.00 | 0.005 | |
| I-133 | 2.95 | 2.86 | 2.86 | 2.89 | 0.042 | |
| Kr-90 | 16 | 14 | 13 | 14.33 | 1.247 | |
| Ni-65 | 20 | 18 | 16 | 18.00 | 1.633 | |
| Rh-106 | 79 | 75 | 73 | 75.67 | 2.494 | |
| Te-129M | 4.5 | 4.2 | 4.1 | 4.27 | 0.170 | |

****

**Figure 10:** Radionuclide activities of S5 beam tube water drain

1. Radionuclides measurement result for beam tube S6 liquid radwaste

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  |
| Zn-65 | 1410 | 1390 | 1390 | 1396.67 | 9.43 |
| Co-60 | 567 | 558 | 558 | 561.00 | 4.24 |
| Co-57 | 980 | 975 | 970 | 975.00 | 4.08 |
| Rh-106 | 610 | 610 | 606 | 608.67 | 1.89 |
| Cd-109 | 580 | 580 | 575 | 578.33 | 2.36 |
| Mn-54 | 96 | 104 | 100 | 100.00 | 3.27 |
| Ti-44 | 34 | 31 | 28.0 | 31.00 | 2.45 |
| Ho-166 | 24 | 23 | 22 | 23.00 | 0.82 |
| Cs-137 | 15 | 14 | 14 | 14.33 | 0.47 |
| Ag-110m | 26 | 29 | 25 | 26.67 | 1.70 |
| Zr-95+ | 6.1 | 6 | 5 | 5.70 | 0.50 |



**Figure 11:** Radionuclides found on water drain of the S6 beam tube

1. Radionuclides measurement result for mechanic filter flushing of KBE-02

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Nuclides** | **Activity, Bq** | | | **Average** | **Std-dev** |
|  | **1st** | **2nd** | **3rd** |  |  |
| Kr-90 | 80 | 76 | 78 | 78.00 | 1.633 |
| Br-84 | 3.4 | 3.1 | 5.6 | 4.03 | 1.115 |
| Kr-89 | 2.1 | 3.6 | 4.4 | 3.37 | 0.953 |
| Xe-133 | 1.76 | 1.4 | 1.65 | 1.60 | 0.151 |
| Ni-65 | 0.94 | 0.94 | 1.46 | 1.11 | 0.245 |
| Cr-51 | 0.93 | 0.0122 | 0.92 | 0.62 | 0.430 |
| Ce-144 | 0.144 | 0.143 | 0.168 | 0.15 | 0.012 |
| Mn-54 | 0.09 | 0.08 | 0.09 | 0.09 | 0.005 |
| Fe-59 | 0.084 | 0.08 | 0.084 | 0.08 | 0.002 |
| Co-60 | 0.123 | 0.1045 | 0.118 | 0.12 | 0.008 |
| Ce-141 | 0.071 | 0.0648 | 0.086 | 0.07 | 0.009 |
| I-132 | 0.0418 | 0.05 | 0.066 | 0.05 | 0.010 |
| Te-132 | 0.04 | 0.0342 | 0.039 | 0.04 | 0.003 |
| Nb-95 | 0.0272 | 0.0272 | 0.0285 | 0.03 | 0.001 |
| Zr-95 | 0.0294 | 0.0104 | 0.0321 | 0.02 | 0.010 |
| Co-58 | 0.022 | 0.022 | 0.023 | 0.02 | 0.000 |
| La-140 | 0.0203 | 0.0064 | 0.0398 | 0.02 | 0.014 |
| Xe-133M | 0.023 | 0.02 | 0.023 | 0.02 | 0.001 |
| I-131 | 0.0154 | 0.0177 | 0.0206 | 0.02 | 0.002 |
| I-134 | 0.018 | 0.018 | 0.017 | 0.02 | 0.000 |
| Ba-140 | 0.012 | 0.012 | 0.01 | 0.01 | 0.001 |
| Ru-103 | 0.0106 | 0.0106 | 0.0121 | 0.01 | 0.001 |
| Nd-147 | 0.0071 | 0.0071 | 0.0102 | 0.01 | 0.001 |
| Te-131M | 0.0073 | 0.0073 | 0.0071 | 0.01 | 0.000 |



**Figure 12:** Radionuclides identified in water drain of filter washing of KBE02 purification system